DRIVE SYSTEM FOR COUNTER-ROTATING PROPELLERS

BACKGROUND OF THE INVENTION

Cross-Reference to Related Application

This application is a continuation of and incorporates by reference co-pending Application Serial No. 09/766,878, filed January 19, 2001, which claims priority from provisional application Serial No. 60/177,051, filed January 20, 2000, which are commonly owned with the present invention and which are incorporated herein by reference.

Field of the Invention

The present invention relates to propulsion mechanisms for vessels driven by propellers, and, more particularly, to transmissions for aircraft and airboats, and to lubrication systems therefor.

Description of Related Art

Transmissions for driving a pair of counter-rotating propellers are known in the art for both airplanes and airboats. Such transmissions are known to be driven by belts and by gears, with input typically provided by a shaft driven by an aircraft engine operating at approximately 2500-3000 revolutions per minute (rpm). Aircraft engines are extremely expensive, noisy, and fuel inefficient.

Airboat systems that utilize belt-driven transmissions are inefficient owing to power losses caused by belt friction, especially at higher rotational velocities. Belt breakage in these systems is a source of failure. Another disadvantage of belt-driven systems is their inability to permit reduction of engine speed, since the shaft used to effect such a reduction

would have to be too small to be practicable. Thus it has been deemed advantageous to utilize a different transmission method in an airboat to enable engine speed reduction without loss of efficiency.

A belt-driven, two-engine counter-rotating system has been disclosed by Stewart (U.S. Pat. No. 4,426,049). It has been taught by Becker et al. (U. S. Pat. No. 4,932,280) to use coaxial drive shaft systems for driving multiple outputs from a single input in an aircraft. Gearing means are disclosed for driving two outputs at different speeds.

A double-sprocket and wheel transmission for driving multiple propellers in the same direction is described by Fay (U.S. Pat. No. 1,329,387).

The use of a gear-based transmission for airboats has been taught by Kaye (U.S. Pat. No. 5,807,149), including a transmission for driving a pair of counter-rotating coaxial shafts, to each of which is affixed a propeller. Such an arrangement can be used with an automobile engine, which is far more economical than an aircraft engine. This transmission has been shown to reduce noise and torque, to permit varying gear ratios, to increase fuel efficiency and engine life, and to be less expensive to operate.

Improved gear-based transmissions for airboats have also been disclosed by Jordan (U.S. Pat. Nos. 5,724,867 and 6,xxx,xxx, the entire contents of both of which are incorporated herein by reference). In the 'xxx patent a lubrication system is also taught that includes a gear for driving lubricant from a well to the interior of the inner output shaft, out of that space to a pair of stiffener bearings, and into the space between the output shafts.

Another source of failure in transmissions is failure of the oil pump that heretofore has been considered an essential element.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a transmission that has improved strength and stability characteristics for driving a pair of counter-rotating propellers.

It is a further object to provide such a transmission having a single input shaft for driving means for driving the two output driven shafts.

It is another object to provide a transmission for driving coaxial counter-rotating propellers that is drivable at variable or equal speeds as desired.

It is an additional object to provide such a transmission with which it is possible to drive the counter-rotating propellers at different speeds to provide additional thrust, reduce noise output, and improve fuel efficiency.

It is also an object to provide such a transmission that is considerably lighter than previously known devices.

A further object is to provide a system and method for lubricating the output driven shafts that reduces weight and complexity.

Another object is to provide a system and method for achieving a simplified lubrication of a transmission and propulsion for an airboat.

An additional object is to provide such a system and method that eliminates the need for an oil pump to circulate lubricant.

These and other objects are achieved by the transmission of the present invention, which is for driving a pair of coaxial, counter-rotating propellers for, for example, an airboat or an aircraft, although these are not intended as limiting usages. The transmission is housed in a case that has an interior space.

A drive shaft extends from the outside of the case into the interior space and is rotatable in a first direction. When the transmission is in use on an aircraft or airboat, the drive shaft is mated at one end to a motor crank extending from and rotated by an engine. As mentioned above, previously known aircraft and airboats have utilized aircraft-type engines; however, with the transmission of the present invention, it has been found that an automobile engine can be used. This has a benefit of reducing cost, as well as other benefits to be discussed below.

A first driven shaft also extends into the interior space of the case, typically from a side opposite that of the drive shaft. The first driven shaft is for rotating an outer propeller, that is, the propeller farther from the airboat body.

A second driven shaft, which is hollow, likewise extends into the interior space of the case and is further positioned in surrounding, generally coaxial arrangement to the first driven shaft. The second driven shaft is shorter than the first, and both ends protrude beyond the ends of the first driven shaft. This second driven shaft is for rotating an inner propeller, that is, the propeller closer to the airboat body.

A gear train for driving the first shaft is housed in the interior space of the case. In its simplest configuration, the gear train comprises two gears: a drive gear and a driven gear. The drive gear is coaxially affixed to the drive shaft. The driven gear is coaxially affixed to the first shaft in such a position and configured so as to be rotatable by the drive gear. Thus, when the drive shaft rotates in the first direction, the drive gear is rotated in the first direction. This causes the first driven gear to be rotated in a second direction opposite in sense to the first direction, which consequently drives the first shaft in the second direction.

In an alternate embodiment, additional intermediate driven gears may be interposed between the drive gear and the first driven gear, so long as the total number of intermediate gears is an even number.

A sprocket train is also housed in the interior space of the case. This sprocket train includes a first and a second sprocket and a chain. The first sprocket is coaxially affixed to the drive shaft. The second sprocket is coaxially affixed to the first shaft. The chain is in engagement with both sprockets and is in such a position and configured so as to rotate the second sprocket upon the first sprocket turning. Thus, when the drive shaft rotates in the first direction, the first sprocket is rotated in the first direction. This causes the second sprocket also to be rotated in the first direction, which consequently drives the first shaft in the first direction.

Thus it can be seen that the rotation of the drive shaft in one direction achieves, through the action of the hybrid transmission comprising the gear train and the sprocket train, a counter-rotation of the two coaxial driven shafts and thus imparts counter-rotation to propellers attached thereto. There is no known system that uses fewer components than that of the present invention, which permits lower weight, improved efficiency, and enhanced reliability.

Using the present hybrid gear/sprocket transmission permits driving an automobile engine at the point of maximum horsepower, which generally implies a motor crank rotational speed approximately in the range of 5000-5200 rpm, and then gearing down the rotational speed to roughly 1200-2800, possibly even lower, a quieter speed at which to run the propellers.

The invention is not, of course, limited to the use of an automobile engine; in fact, the presence of the gear and sprocket trains enables the user to optimize for efficiency and noise characteristics by altering gear ratios as desired. An aircraft engine may also be used.

Yet another feature of the present invention is an improved lubrication system, in which an oil pump is no longer necessary, owing to the presence of the two coaxial driven shafts, between which lubricant may pass and be moved by the counter-rotation thereof. This feature of the system comprises means for injecting a lubricant into a space between the driven shafts and means for blocking the entry hole during use to retain the lubricant therein.

Among the benefits of the present invention are a minimization of components, which is believed to increase reliability and dependability, and a decrease in the weight, which increases performance and fuel efficiency. Present counter-rotator transmissions known in the art have a weight of 140-200 lbs, whereas the hybrid transmission of the present invention has a weight in the range of 90-110 lbs.

The features that characterize the invention, both as to organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description used in conjunction with the accompanying drawing. It is to be expressly understood that the drawing is for the purpose of illustration and description and is not intended as a definition of the limits of the invention. These and other objects attained, and advantages offered, by the present invention will become more fully apparent as the description that now follows is read in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side cross-sectional view of a first embodiment of a transmission for driving counter-rotating propellers, also showing the shaft lubrication system.

FIG. 2 is a side cross-sectional view of a second embodiment of a transmission for driving counter-rotating propellers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A description of the preferred embodiments of the present invention will now be presented with reference to FIGS. 1 and 2.

The hybrid transmission **10** of the present invention, shown from the side in FIG. 1, which is designed to drive a pair of coaxial, counter-rotating propellers **20** and **30**, comprises a case **50** that has an interior space **502**, a fore side **504**, and an aft side **506**. It is preferred that the case exterior be aerodynamically shaped in order to confer good airflow characteristics to the transmission **10** during use at high speeds.

A drive shaft **12** extends into the interior space **502** of the case **50** through the case's fore side **504**. The drive shaft **12** is rotatable in a first direction, shown here as counterclockwise when viewed from the front. Typically the drive shaft's fore portion **122**, which extends outside the case **50**, contains a coupler **124** for mating with a crank shaft **62** from an engine **60**, which generates the rotational motion. The drive shaft **12** is preferably configured as a through shaft with respect to the case **50**, and is thus supportable via brackets **508,509** affixed on the inside of both the fore **504** and the aft **506**

sides, respectively, of the case's interior space **502**. This dual support confers exceptional stability to the drive shaft **12.**

The outer propeller **20** is mounted via propeller mount **202** adjacent the aft end **224** of, and is rotated by, a first driven shaft **22** that extends from the back side **506** into the interior space **502** of the case **50**. The fore end **222** of the outer propeller **20** is supported via bracketing **510** on the inside of the case's fore side **504**. Preferably the first driven shaft **22** comprises a hollow shaft, having a lumen **221** therethrough. A removable cap **223** at the aft end **224** leads to the lumen **221**, as does a hole **225** adjacent the fore end **222**.

The inner propeller **30** is mounted via propeller mount **302** to the aft portion **324** of, and is rotated by, a second hollow driven shaft **32** that extends from the aft side **506** into the interior space **502** of the case **50**. The second hollow shaft **32** is positioned in surrounding, generally coaxial arrangement to the first hollow driven shaft **20** and is shorter than the first driven shaft **22**. These relative lengths permit the fore end **222** and the aft portion **224** of the first driven shaft **22** to protrude, respectively, beyond the fore end **322** and the aft portion **324** of the second driven shaft **32**. The second driven shaft **32** is supported on the interior of the case's aft side **506** by bracketing **511**.

In a preferred embodiment the longitudinal axes of the drive shaft **12** and the first **22** and second **32** hollow driven shafts are positioned generally in vertical alignment. This positioning confers improved stability during use, as the gyroscopic forces balance optimally in this configuration.

The transmission **10** of the present invention further comprises two drive trains housed within the case **50**, one for driving each of the hollow driven shafts **22,32**. The first

train **40** comprises a gear train comprising an even number of gears for changing the incoming rotational direction. The embodiment shown in FIG. 1 contains two gears: a drive gear **402** coaxially affixed to the drive shaft **12** and a driven gear **404** coaxially affixed to the first hollow shaft **22**. The driven gear **404** is positioned and configured so as to be rotatable by the drive gear **402**. Thus, when the drive shaft **12** rotates in the first direction, here shown as counterclockwise, the drive gear **402** is rotated in the same direction, and the driven gear **404** is rotated in a second direction opposite in sense to the first direction, that is, clockwise. Thus the first hollow shaft **22** is driven in a clockwise direction also, as would be an attached propeller **20**.

The second drive train **42** comprises a sprocket train for maintaining the incoming rotational direction. The sprocket train **42** comprises a drive sprocket **422**, a driven sprocket **424**, and a chain **426**. The drive sprocket **422** is coaxially affixed to the drive shaft **12**, and the driven sprocket **424** is coaxially affixed to the second hollow shaft **32**. The chain **426** is positioned in encompassing relation to the teeth of the sprockets **422,424** and is configured so as to rotate the driven sprocket **424** upon a rotation of the drive sprocket **422**. Therefore, in use, when the drive shaft **12** rotates in the first direction, the drive sprocket **422** is rotated in the first direction, the driven sprocket **424** is also rotated in the first direction, and the second hollow shaft **32** is rotated in the first direction, conferring counter-rotational movement to the inner propeller **30** with respect to the outer propeller **20**.

In an alternate embodiment **10'** (FIG. 2), the gear train **40** and the sprocket train **50** are interchanged in axial position, with the gear train **40** driving the second hollow driven shaft **22** and the sprocket train **50** driving the first hollow driven shaft **32**.

Particular benefits of the hybrid propulsion system of the present invention include the possibility of using an even number of gears, since a planetary, intermediate, sense-changing gear is no longer necessary to achieve counter-rotation. In addition to the weight and commensurate efficiency advantage conferred thereby, stability is also improved, with balancing force vectors conferring added reliability and durability. For example, failures are known to have been caused by outward-pointing forces imposed upon the planetary gear by the driving and driven gears. Further, all the gears in the present invention are mounted on through shafts, which are also stronger and more stable.

In either of the above-detailed embodiments it may be seen that the first and the second drive trains can be adapted to drive the propellers at different speeds, if desired which can provide improved thrust characteristics, increased fuel efficiency, and reduced noise.

Shaft Lubrication System

An additional aspect of the present invention comprises a lubrication system for delivering lubricant to elements of the propulsion system. A particular embodiment of the lubrication system, illustrated in FIG. 1, comprises means for injecting, sealing, and circulating a lubricant within an enclosed space including the hollow shafts **22,32** without the use of a mechanical pump. Upon removal of the cap **223**, lubricant may be injected

into the inner shaft's lumen **221**. The rotational motion of the shaft **22** drives lubricant via "centrifugal force" from the inner shaft's lumen **221** out through a plurality of holes **228** in the aft portion of the shaft **22** to enter the space between the shafts **22,32**, where there are positioned a plurality of floating cylindrical bearings **66**, which maintain the distance between the shafts **22,32** and also assist to distribute lubricant. In a preferred embodiment there are between two and four of these bearings **66** positioned in spaced relation from each other between the shafts **22,32**, and the material comprises brass. Although brass is disclosed herein, it will be understood by one of skill in the art that another material may be used, preferably a metal dissimilar from the material of which the shafts **22,32** are composed.

In order to provide a path for the escape of trapped air in the space to be lubricated, a toroidal collar **44** is provided that is positioned around the inner shaft **22** between the gear **404** and the bearing **510**. To an upper end of the collar **44** is affixed a line **45** that leads at a top end from the case's **50** top side **512**, and is sealable with a removable cap **46**. The line **45** leads at a top end to a void **441** in the collar **44** that surrounds the inner shaft **22**. Two O-rings **47** are positioned in surrounding relation to the collar **44** around the inner shaft **22** to prevent lubricant from leaking out from the void **441** to the exterior of the inner shaft **22**. Thus, in use, lubricant that has been injected into the inner shaft's lumen **221** also proceeds forward through the lumen **221** and reaches the collar's void **441**. Any air bubbles that have been trapped along the way can then escape through the uncapped line **45**, and then the cap **46** can be replaced. The collar **44** does not turn with the shaft **22**, but rather floats thereon, being held substantially in place by the line **45**.

The bearings **66** themselves represent a novel lubrication element, being designed to maximize lubricant return in the fore direction. In a preferred embodiment each bearing **66** has a series of generally helical grooves **662** cut in the outer surface, through which the lubricant may move to be distributed within the outer shaft **32**.

This lubrication system eliminates the oil pump and associated gear previously known and used in the art, and thus also improves fuel efficiency by reducing weight by 15-20 lbs.

It may be appreciated by one skilled in the art that additional embodiments may be contemplated, including variable numbers and sizes of gears, which may be positioned and configured to permit variable relative speeds of the two counter-rotating propellers.

In the foregoing description, certain terms have been used for brevity, clarity, and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such words are used for description purposes herein and are intended to be broadly construed. Moreover, the embodiments of the apparatus illustrated and described herein are by way of example, and the scope of the invention is not limited to the exact details of construction.

Having now described the invention, the construction, the operation and use of preferred embodiment thereof, and the advantageous new and useful results obtained thereby, the new and useful constructions, and reasonable mechanical equivalents thereof obvious to those skilled in the art, are set forth in the appended claims.